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Scallop Fishery Assessment of the Southern Gulf of St. Lawrence in 2010: Commercial Fishery Data

Évaluation de la pêcherie de pétoncles dans le sud du golfe du Saint-Laurent en 2010 : données de la pêche commerciale

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ABSTRACT

The only index of abundance available for the Gulf Region scallop stock is from the catch and effort data of the commercial fishery. Mandatory logbooks have been in effect since 2001 but there is incomplete compliance which adds to the uncertainty in the reliability of the landings and the effort data and the calculation and interpretation of catch per unit of effort (CPUE) data. Based on historical information, scallop stock abundance in the southern Gulf of St. Lawrence (sGSL) is low and only 25% of licence holders are active. The benefits of area closures to scallop bed rebuilding have been documented in the literature but have not been examined in the sGSL. The closed areas in Scallop Fishing Areas (SFA) 21A, 21B and 22, when reopened, would be good case studies. Buffer zones were instituted for lobster conservation reasons not scallop stock rehabilitation. No new information was reviewed to assess the effectiveness of the buffer zone measures on lobster conservation. In the sGSL, there was no proposal for a change in drag ring size so the change to population structure of the harvested scallop and consequential yield was not assessed for this document. Scallop dredging has little impact on habitat and on the bycatch of groundfish or crustaceans.

RÉSUMÉ

Le seul indice d'abondance disponible pour le pétoncle de la Région du Golfe est tiré des données sur les prises et l'effort de la pêche commerciale. Des registres de bord obligatoires sont en vigueur depuis 2001, mais la conformité n'est pas généralisée, ce qui ajoute à l'incertitude quant à la fiabilité des données sur les débarquements et l'effort, de même qu'au calcul et à l'interprétation des données sur les prises par unité d'effort (PUE). D'après les statistiques historiques, l'abondance des stocks de pétoncles du sud du golfe du Saint-Laurent (sGSL) est faible et seulement 25 % des titulaires de permis sont actifs. Les avantages de la fermeture de zones pour le rétablissement des gisements de pétoncles sont documentés dans certaines études, mais celles-ci ne portent pas sur le sGSL. Les zones fermées dans les zones de pêche du pétoncle (ZPP) 21A, 21B et 22, lorsqu'elles seront rouvertes, feraient de bonnes études de cas. Les zones tampons ont été établies pour des raisons de conservation des homards et non pas de rétablissement des stocks de pétoncles. Aucune nouvelle donnée n'a été examinée pour évaluer l'efficacité des zones tampons sur la conservation du homard. Dans le sGSL, il n'y a aucune proposition de changement de la taille des anneaux des dragues, de sorte que le changement de structure de la population des pétoncles récoltés et le rendement connexe n'ont pas été évalués aux fins du présent document. Le dragage du pétoncle a peu d'effet sur l'habitat et sur les prises accessoires de poissons de fond ou de crustacés.

INTRODUCTION

BIOLOGY

The sea scallop (*Placopecten magellanicus*) is a bivalve mollusc found in the Atlantic coastal waters that has a geographical range from the north shore of the Gulf of St. Lawrence (Squires 1962) to Cape Hatteras, North Carolina (Posgay 1957). They are benthic dwellers, living at the sediment-water interface and are semi-mobile active filter-feeders ingesting phytophankton, small zooplankton, pollen grains, ciliates, detritus material and bacteria (Shumway *et al.* 1987). Scallops frequently occur in dense local populations called beds which may be extensive enough to support commercial fisheries (Bourne 1964). They are usually found in depths ranging from about 10 to 100 m but may be found in shallower water (Verrill and Smith 1873). In the southern Gulf of St. Lawrence (sGSL), scallop beds are located at depths of 15 m to 37 m. Sea scallops seem to prefer sand-gravel or gravel-pebble substrates although they are occasionally found on sand-mud or rocky bottoms (Couturier *et al.* 1995). Fishable concentrations are associated with strong tidal circulations (Tremblay and Sinclair 1988) or located in areas of persistent gyres (Caddy 1979; Posgay 1979). According to Naidu and Robert (2006) the question whether scallop beds are self-sustaining has not been resolved and the relationship between the source of recruitment and the degree of temporal stability of a bed has not been shown.

Commonly reaching shell height sizes between 100 to 150 mm, the largest sea scallop ever recorded measured 211 mm (shell height = tangential dorso-ventral measurement) (Naidu 1991). In the sGSL large scallops commonly reach between 125 and 145 mm. Annual rings are formed on the shell each year at the time of cold water (Bourne 1964). Rings are especially pronounced in northern shallow-water populations (Naidu 1975) like in the sGSL. Oxygen isotope records have confirmed that growth lines are annual events (Tan *et al.* 1988). Sea scallop growth rates are highly variable, depending on location (Naidu and Robert 2006). Scallops can be aged by counting these rings and the growth rate can be determined by measuring the distance between annular rings (Stevenson and Dickie 1954). Growth rates calculated from various aggregations are reported usually in the form of von Bertalanffy growth equation (Naidu and Robert 2006). Posgay (1953) reported that scallops living in an area with a narrow temperature range near 10°C exhibited the best growth. Growth occurs at temperature ranging from 8°C to 18°C while the ideal temperature for growth is 13.5°C (Frenette, 2004). Growth rates have been shown to be negatively correlated to a combination of temperature and food availability (MacDonald and Thompson 1985).

Sea scallops prefer salinities of 30 to 32 ppt but they can tolerate salinities as low as 25 ppt (Couturier *et al.* 1995). In the sGSL, scallops must often face temperatures ranging from -2°C to 20°C (Frenette 2004). The sea scallop is stressed at temperatures between 20°C to 23°C yet will survive if acclimated. Mass mortality will occur at temperatures of 23.5°C or greater (Dickie, 1958).

The sexes are separate, with males and females being identified by the colour of the gonad when it is ripening: the male gonad is white and the female gonad is orange to brick red (Drew 1906). Sexual differentiation occurs at an age of 1+, yet, most sea scallops do not effectively release their gametes until they reach a shell height > 70 mm (approximately 3 years old in the sGSL). Scallops are considered to reach the adult stage when their shell height is >81mm (Davidson 1998). However, Bonardelli and Himmelman (1995) demonstrated that in some areas, the adult stage is only reached at greater shell height. Fecundity varies from one year to another and is exponentially related to the shell height (Langton *et al.* 1987). Sex ratio of males: females is usually 1:1 and hermaphrodites are occasionally observed in the adult population

(Worms and Davidson 1986). In the sGSL, spawning usually occurs in the fall (Davidson 2007). The males and females release their gametes synchronously and fertilisation occurs in the water column. The larvae are planktonic for 4 to 5 weeks after which time they metamorphose and settle on suitable substrates to begin their benthic life (Culliney 1974).

DESCRIPTION OF THE FISHERY

The sea scallop fishery in the southern Gulf of St. Lawrence (sGSL) is managed by the Gulf Region through the establishment of fishing areas, limited entry, seasons, meat count limits and gear restrictions. Catches are monitored through logbooks filled in by the scallop harvesters. In the Gulf Region, the price paid to harvesters increased from \$0.57/kg (\$0.26/lb) in 1967 to \$17.64/kg (\$8/lb) in 1994 and have since been fluctuating between \$13.26 and \$19.84/kg (\$6/lb and \$9/lb) (Mallet 2010).

FISHING AREAS

First recorded landings were in the early 1900's and from 1923 to the early 1980's, scallop harvesters were allowed to fish the entire Gulf of St. Lawrence. In the early 1980's legislations were put into place to confine scallop fishing activities of each scallop harvester to one particular fishing area (Lanteigne and Davidson 1991).

The scallop grounds in the Gulf Region are divided into four Scallop Fishing Areas (SFA) with one zone (SFA 21) divided into three sub-zones (Fig. 1). Each SFA and sub-zone has its own management strategies. Prior to 1996, the SFAs 21A, 21B and 21C were one large fishing area, SFA 21. The scallop harvesters accepted the sub-division to facilitate the management of a scallop enhancement project conducted by the Maritime Fishermen's Union (MFU).

NUMBER OF LICENCE HOLDERS

The scallop fishery in the Gulf Region has had limited entry since the seventies. Presently, there are 774 scallop harvesters that hold a commercial scallop fishing licence (Table 1). Thirteen First Nations have access to the scallop resources. In SFA 21, the 103 scallop harvesters that hold licences are from northern and eastern New Brunswick (NB) (28 in SFA 21A, 27 in SFA 21B and 48 in SFA 21C). In SFA 22, of the 203 scallop harvesters holding licences, 142 are from eastern NB and 61 are from Prince Edward Island (PEI). In SFA 23, all 78 scallop harvesters holding licences are from PEI. In SFA 24, there are a total of 390 scallop harvesters holding licences with 131 being from Nova Scotia (NS) and another 259 from PEI.

FISHING SEASONS

One of the management strategies used to control the fishing effort is to limit the fishing season. Each SFA has its own fishing season which is selected following a discussion and agreement by licence holders and the Department of Fisheries and Oceans (DFO) managers. The fishing season of other commercial stocks such as lobsters often influence the scallop harvesters' choice for the scallop fishing season. Also, the scallop harvesters often agree to shorten a fishing season when their catch per day decreases. The fishing season dates selected by scallop harvesters from 2008 to 2010 are presented in Table 2.

MEAT COUNT

In the Gulf Region, all harvesters are required to shuck the meat from the scallop shells at sea therefore all scallop catches are in meat weights. There is no scallop shell minimum size and

there are no quotas but the number of scallop meats per half kilogram is regulated. The meat count can vary from SFA to another (Table 2). During the fishing season, fishery officers board fishing vessels or meet them at the wharf to verify the meat count of the blended catch. An officer will test a sample of the catch by filling a calibrated container that is known to hold ½ kg of scallop meats and then counting the number of meats in the container. Blending the catch before it is verified allows the scallop harvesters to shuck a few scallops that have not reached the adult stage.

FISHING GEAR

In the Gulf Region, the typical fishing vessel is a 14 m (45') stern or side dragger. Most of the scallop harvesters use a Digby-type dredge with 5 to 15 toothed buckets (Fig. 2); however, a sweep chain drag is sometimes used.

Following a study comparing different gear configurations (Parsons and Davidson 2004) scallop harvesters in all SFAs accepted to construct the buckets of their dredge with a maximum of 8 steel washers attached to one ring (2 per side) with chaffing gear or with 2 rubber washers on the vertical, a rubber washer attached on the top and on the bottom of each ring (Fig. 3). Rubber washers, like chaffing gear, prevents the wear and tear of the rings.

Prior to 2000, the minimum diameter ring size in all SFAs was 76 mm (3"). SFA 22 was the first SFA to adopt the 82.6 mm (3 ¼") ring size and the other SFAs soon followed. Scallop harvesters agreed to increase the ring size based on results of an unpublished study, conducted in the Gulf Region, which compared the catch of buckets with various ring sizes. Results indicated that the total catch using 76 mm (3") was not significantly different than the catch of buckets with 82.6 mm (3 ¼") rings. Yet, the buckets with 82.6 mm (3") rings retrieved less scallops smaller than 76 mm.

The acceptable total length of the dredge, the ring size, the type and number of washers and the tow bar are described in the condition of licence for each SFA (Table 3).

Many scallop harvesters in SFA 21A feel that the 6 m dredge is too long and too heavy. Yet, the ideal length and weight of the dredge for the scallop fishery in the Gulf Region has not been evaluated. In SFA 22, many scallop harvesters have very heavy tow bar which was presumed to behave as a plough on the bottom. Scallop harvesters in SFA 22 have accepted to place 50.8 mm (2") high runners on each end of the tow bar to keep it from scrapping the bottom. The effect of a heavy tow bar with runners or without runners has not been investigated.

LOGBOOKS

Since 1998, mandatory logbooks were included in the condition of licence but the scallop harvesters were given a grace period for compliance. Therefore the logbook data has only been used to report the landings since 2001. The logbook was designed to capture the fishing effort and landing data (Fig. 4).

BUFFER ZONES

In the Gulf Region, buffer zones have been implemented to prevent the scallop harvesters from dragging over selected habitat. The buffer zones are mainly aimed at protecting the habitat of immature lobsters but may also serve to protect sensitive habitat. The fishing industry from each SFA and DFO managers collaborated to establish buffer zones. As a result, buffer zone criteria vary from one SFA to another. In SFA 21A, the buffer zones were established to protect habitat

in water less than approximately 15 m (50 ft). Many scallop harvesters in SFA 21A, feel that the coordinates for the actual buffer zone line should be adjusted because they are not all located in the appropriate areas to respect 15 m (50 ft) and some feel the buffer zone should be set at 16.8 m (55 ft) instead of 15 m (50 ft). In SFA 21B, a buffer zone was imposed to protect the lobster fishing grounds inside Chaleurs Bay but off the east coast of Miscou and Shippagan Islands there are no official buffer zones. In SFA21C there are no official buffer zones. Scallop harvesters from SFA 22 accepted a buffer zone which protects all habitats in water less than 11 m (36 ft), mainly aiming to protect the lobster larval settling areas which are usually less than 9 m (30 ft) (Comeau 2007). In SFA 23, there are no official buffer zones but scallop harvesters have a gentlemen's agreement of only dragging in waters deeper than 27.4m (90 ft). In SFA 24, a large portion of the habitats in water less than 9 m is not protected yet an area in deeper water is protected. Many scallop harvesters in SFA 24 feel that their buffer zones should be evaluated to determine if they are effective while another group of scallop harvesters would like additional buffer zones. This controversy has prompted DFO managers to initiate a buffer zone and closure policy. This policy is still being developed.

Also, in 2005 an area west of the Confederation Bridge was closed by variation order at the request of the scallop harvesters in SFA 22 (Fig. 5). This area was closed to allow the scallop stock to rebuild. Similarly, in 2010 the entire SFA 21A has been closed. These closed areas can be re-opened at the request of the scallop harvesters.

STOCK ASSESSMENT

LANDINGS

Scallop harvesters in the Gulf Region land only the meat. In the past, the meat with roe was occasionally landed. The fisheries statistics identify three types of scallop landings: meat weight, meat with roe weight and live weight. Meat weight is converted to live weight using a multiplier of 8.3 while roe and meat is considered as live weight landings and a conversion factor is not applied (Lanteigne and Davidson 1991).

Scallop landings are obtained from commercial sale transaction slips and since 2001, from mandatory logbooks. From 1982 to the implementation of the logbook, DFO's fishery officers were asked to fill supplementary B forms to estimate the amount of scallops sold to non-registered buyers. Commercial sale transaction slips that are given by registered buyers are recorded in DFO's statistics. Scallop harvesters are required to record in their logbooks the amount of scallops sold to registered buyers and the amount sold locally and kept for personal use (Fig. 4). The landing data acquired from the sale slips that are provided by the registered buyers include the statistical district where the scallops are sold (Fig. 6). To determine the total landings for each SFA, sale slips and estimates from supplementary B form from all the statistical districts in each SFA must be added (Table 4).

The total yearly scallop meat landings and the number of days fished in the Gulf Region are presented in Figure 7. The commercial fishing vessel (CFV) number has consistently been recorded on each sale transactions slips since 1985-1986 (Lanteigne and Davidson 1991). Therefore, since 1986 a rough estimate of the number of fishing days (Fig. 8), and of the number of active fishing vessels can be derived from landing data assuming that the landed quantity recorded on one sale slip is the catch of one fishing day and that each CFV number represents one fishing vessel.

CATCH STATISTICS

The only index of abundance available is from the catch and effort (CPUE) data of the commercial fishery. The assumption is that the catch rates are proportional to abundance. The logbook data provides the best information but the usable time series only begins in 2001. The effort data from logbooks was standardized to hour per metre of dredge. When effort was not recorded in logbooks or for landings data for which no logbooks were returned, the total effort is estimated using the CPUE corrected by the total reported landings. The percentage of the fishing days tabulated from logbooks relative to the fishing days estimated from the purchase slips data decreased after 2004 in most SFAs with the exception of SFA 24 where the percentage has been high (> 95%) over the entire time period (Fig. 9). The consequence of missing logbook data is added uncertainty in the reliability of the landings and the effort data and the calculation and interpretation of CPUE data.

The CPUEs have generally been highest in SFA 22, with mean values around 0.75 to 1.00 kg per hr per m, and lowest in SFA 21A and 21C (Fig. 10). The regulatory meat weight count is lower in SFA 24 because the fishery occurs in the fall (highest meat count per 500 g regulation). The CPUE within SFAs shows high variability within years but without a trend in most of the SFAs over the ten year period (Fig. 10). In SFAs 21A and 21C, there was no trend in CPUE during a time when effort declined substantially, by more than 50% in SFA 21A and by 98% in SFA 21C (Fig. 10). This differs from SFA 22 where there is no temporal trend in either CPUE or effort during 2001 to 2010. In SFA 24, effort has declined by about 25% over the time period with no trend in CPUE. Declining efforts even though the recorded catch rates have not decreased is often consistent with low or even declining abundance of the resources because scallop harvesters voluntarily stop fishing when it is no longer profitable.

EFFORT DISTRIBUTION

Since the implementation of the logbook, distribution of reported effort can be mapped. The position reported in the scallop harvesters' 2009 logbooks can be found in Figure 11 and the 2001 to 2008 maps of fishing effort are found in Figure 12.

Worms and Chouinard (1983, 1984) had identified the locations of the scallop beds based on the data retrieved from scallop surveys conducted in 1982 and 1983. Even though the scallop harvesters are only reporting one position per day in their logbook, mapping those positions seems to well delineates scallops beds locations which are similar to those reported by Worms and Chouinard (1983, 1984). Therefore, the scallop bed locations in the sGSL do not appear to have changed since then. Smith et al. (2009) reported an association between scallop abundance and bottom type and depth. Therefore, unless there is a change in bottom type, locations of scallop beds should remain constant.

For the purpose of this report, a scallop harvester is said to be active if at least one landing report is recorded during the fishing season. The number of licences and the number of active licences for each SFA is presented in Table 1 for 2002 to 2010. The number of active scallop harvesters varies every year and in 2009 only 25% of the scallop harvesters reported to be active.

SEA SAMPLING PROGRAM 2001-2005

The main objective of the sea sampling program conducted from 2001 to 2005 was to better understand the scallop stocks. The biological data acquired were the size distribution, age structure and meat yield of scallops from various beds within the sGSL.

FISHING GEAR

There was a wide variety of gear configurations used on the vessels participating in the at-sea sampling (Annex 1). However, all vessels employed during sea sampling were equipped with Digby drags with toothed buckets. Only one side dragger was used (Miscou), while others were stern draggers. The width of the dredge and the gear configurations used on the vessels were recorded at the beginning of the day. Although the number of buckets was lower in SFA 24, the total drag width remained similar to other areas. Most vessels had steel washers with vertical rubber washers used on the vertical attachment of rings, except for SFA 21 vessels and the Inverness vessel in SFA 24. A fishing day consisted of between 15 and 70 tows lasting from 10 to 30 minutes each at a speed of between 2 and 2.7 knots. The number of years of experience of the captain ranged from 5 years to 42 years; however, most (66%) possessed over 20 years of experience.

AT-SEA SAMPLING

The sampling involved one day on a commercial fishing vessel at each selected bed during normal fishing activities. The catch of every second tow was set aside to record the number of scallops and clappers (dead scallops with valves still attached) and their shell height measurements to the nearest millimeter. Also, the geographical position at the beginning and at the end of a tow, the depth, the duration of the tow, the speed of vessel and the bottom type was recorded for that tow. During the day, a sample of 200 whole scallops was retained from the third and/or fifth tow for subsequent analysis in the DFO-Moncton laboratory. When at-sea sampling was not possible, a 200 scallops sample and information on fishing location and gear configuration were obtained from the scallop harvester at the wharf and processed in the laboratory (Table 5).

LABORATORY PROCESSING

Subsequent analysis of the 200 scallops samples included measuring and recording the shell height, width and depth, total weight, gonad weight and muscle weight and the weight of other soft parts, to the nearest 0.01mm and 0.1g. The age was determined by counting annual growth rings on the left valve. Also, the distance between each growth ring was measured to calculate the growth rate.

ANALYSIS

Catch density (scallops/m^2) was calculated by dividing the total scallop count of a tow by the tow distance multiplied by the drag width. Distance was obtained either by geographical positions or by dividing the towing speed by the duration of tow. Estimated scallop densities (abundance) were calculated by multiplying the catch density by a conservative dredge efficiency of 10% (Hanson, 1998). The shell height-meat weight relationships for each area were obtained by performing a regression on the logarithmic transformation of meat weight on that of the shell height. These relationships were then applied to the at-sea sampling shell height data to obtain average meat counts. An average meat count per 500g was calculated for scallops of two size groups by using the appropriate shell height-meat weight relationship. By applying the shell height-meat weight relationship to the at-sea sample of shell heights, it was also possible to estimate the average catch rate of the sampling day. Catch rate is defined as the total catch in kg of meat divided by the number of hours of fishing.

RESULTS

The sea sampling was conducted at several sites in each SFA during their regular scallop fishing season in 2001, 2002, 2003, 2004 and 2005 (Fig. 13, Table 5). Data acquired from the sea-sampling program is reported in Table 6. Various factors influence the growth rates of sea scallops and inadvertently, the meat weight / shell height relationship. The shell height at age is a reflection of the growth rate. Important factors affecting the growth rate are food availability, temperature and the genetic stock of the scallops. Growth rates, the meat weight / shell height relationships and shell height at age vary from one bed to another. However, they were similar from year to year although there was some variability on some of the beds. For the purpose of this report, the data of all beds in each SFA acquired from 2001 to 2005 was combined. The meat weight / shell height relationship for each SFA in presented in Figure 14 and the shell height at age is presented in Figure 15. The average meat weight and the average age for a 90 mm and a 100 mm scallop for each SFA is presented in Table 7.

The shell height size frequency distribution data stemming from the at-sea sampling data taken in 2001, 2002, 2003, 2004 and 2005 are presented in Figures 16, 17, 18 and 19, respectively. Also, the average shell height, meat weight and age for each year are presented in the same figures. Interestingly, the size range observed in the sea sampling data is very similar to the size range observed in the 1982 survey (Worms and Chouinard 1983).

If scallop harvesters and DFO managers were interested in adding a minimum size regulation and maintain the same meat count measure, reviewing the average meat weight for a 90 mm and 100 mm scallop? (not sure what is meant) for the entire SFA would be a logical approach (Table 7). However, the average meat weight of a 90 mm scallop from some of the beds in SFA 24 is lower than the average for the entire SFA (Table 7). Since management measures are applied to the entire SFA, it is important to review the data from each bed before implementing measures.

If a minimum size of 90 mm was adopted as a management measure, it does appear that the present meat count measure would not have to change. An additional benefit to a 90 mm minimum size is that it would most likely eliminate the need for the blending practice. The average meat weight of a 90 mm scallop for each of the bed sampled in 2001, 2002, 2003, 2004 and 2005 along with the average meat weight corresponding to the meat count regulation for the SFA is reported in Table 8.

EVALUATION OF GEAR IMPACT

Jennings and Kaiser (1998) reported that fishing activities lead to changes in the structure of marine habitats and influences the diversity, composition, biomass and productivity of benthic communities. Kaiser et al. (2002) have documented that fishing affects the seabed habitat worldwide on the continental shelf. In the sGSL there is considerable spatial-temporal overlap between the scallop fishery and the distribution of winter skate (*Leucoraja ocellata*). The relationship between the scallop fishery and winter skates was studied because winter skates have been designated as endangered in the sGSL by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). An at-sea sampling bycatch study was undertaken in the sGSL scallop fishery in 2006-2008 to record the number, size, location of capture and post-discard survival potential of incidentally caught winter skate along with all other species. Most winter skate captured in the scallop fishery were released alive and in very good condition, suggesting that post-release survival is high. Based on observed catches and estimates of discard survival, the estimated mean annual exploitation rate (percentage of the population killed) over the study period is 0.14% for juvenile winter skate and 0.06% for adults. This fishing-

induced mortality is very small compared to mortality from other sources (Benoit et al. 2010). Hartog (2003) studied the effects of the scallop dredge on the demersal fish communities and the biological component of the habitat off the shores of Magdalen Islands, Québec. He found that the biomass of the sessile epifauna and marine plants were not reduced at the fished site and there was an increase in diversity. The diversity of fish at the site that was fished was more similar to those at the sites that were not fished than at sites with sandy bottoms.

Arseneau et al. (2003) evaluated the dredging impact on scallop and benthic communities on the Ile Rouge scallop bed, in Saguenay-St-Lawrence Marine Park. The study site had a sandy-gravel substrate with high velocity currents. Analysis of photographic sampling and experimental dredging did not reveal effects of dredging on benthic communities. However, Arseneau et al. (2003) did observe a decrease in scallop size at landing and reported that this suggested that dredging could have an impact on the scallop population.

In the sGSL, protecting the lobster habitat from scallop dredging disturbances is of great concern for harvesters. The sea scallop bottom type preference (Stewart and Arnold 1994) resembles the description of the Type IV lobster habitat reported by Comeau (2007). The benthic lobster habitat has been classified as: Type I: Prime lobster ground; Type II: Good lobster ground; Type III: Marginal lobster ground and Type IV: Poor lobster habitat (Table 9) (Comeau 2007).

Hardy et al. (2008) studied the spatial-temporal lobster distribution in relation to the scallop fishing activities in Baie des Chaleurs, Québec and found limited overlap. The authors reported that their results suggested that the scallop fishery has little direct impact on the adult lobster population. Similarly, Robichaud et al. (1987) studied the lobster stock in relation to scallop gear impact in St. Mary's Bay, Nova Scotia. They found that lobster fishing occurred in most of the Bay while dredging for scallops took place in <7% of the Bay and in areas of low lobster density. They reported that their data suggest little adverse impact on the lobsters by scallop dredging in St. Mary's Bay. According to Comeau (2007), lobster might be seen in transition on the Type IV habitat where most of the scallop beds are located but the lobsters do not reside there permanently. Comeau (2007) stated that lobsters younger than 2 yr old are cryptic and are found at depths less than 9 m (30 ft) and older juvenile lobsters will roam to depths of up to 18 m (60 ft). In the sGSL, the cryptic juvenile lobsters have a carapace length of <25mm (M. Comeau, pers. comm.) and adult lobsters are seen at depths as deep as 36 m (120 ft) in the winter and closer to shore in summer (Comeau 2007).

Scallop harvesters could avoid disturbing the immature lobster habitat by not dredging in water less the 9 m (30 ft) and roaming juvenile as well as immature lobster habitat by not dredging in water less than 18m (60 ft). To minimize accidentally dredging transitioning adult lobster in water greater than 18 m (60 ft), the scallop fishing season could be opened only during the time period when most of the adult lobsters are not in transit. Even though scallop harvesters could avoid capturing lobster with spatial-temporal separation, Hardy et al. (2008) question the indirect impact on lobsters caused by the earlier dredging of the habitat that lobsters will later be used during their transiting period.

LeBlanc (In press) has recently completed a study investigating the impact of the scallop dredge in the sGSL. A Before-After-Control-Impact (BACI) type design with fishing intensity incorporated as a covariable was applied to investigate the short-term impact-fishing intensity and one year recovery-fishing intensity relationships. The impact was defined as the relative changes in benthic taxa abundance between the pre and post treatment sampling, while the recovery was the relative changes in benthic taxa abundances between the pre and one year post treatment. This study was conducted in two ecosystems: one in the Northumberland Strait

and one in Chaleurs Bay. Based on Comeau's (2007) description (Table 9), the Northumberland Strait study site would be classified as a Type IV lobster habitat and the Chaleurs Bay site would be classified as a Type II lobster habitat. LeBlanc (In press) found no significant relationships between changes in taxa abundances and fishing intensity in either ecosystem soon after the disturbance. Natural ecosystem level changes appeared more common than fishing related effects soon after the disturbance in the Baie des Chaleurs and in both ecosystems one year after the disturbance. According to LeBlanc (In press) the fact that no significant impact of dredging was found can be interpreted in two ways: 1) there is really no impact of dredging or 2) there were impacts but the experiments did not have sufficient statistical power to detect them. The author concluded that the benthic communities in naturally dynamic environments (shallow water depth = frequent disturbance by storms) are likely naturally selected to be resilient to disturbances. Stokesbury and Harris (2006) who had the opportunity to study the impact of scallop dredging on the epibenthic community on a section of the Georges Bank that had been previous closed, found similar results. At their study site, the sea scallop and the starfishes comprised more than 84% of the fauna. Similary, in the sGSL, results of a study investigating the bycatch of the scallop dredge fishery revealed 81% of the catch is sea scallops and sea star (unpublished data). Stokesbury and Harris (2006) concluded that the limited short-term sea scallop fishery on Georges Bank appeared to alter the epibenthic community less than the natural dynamic environmental conditions. Conversely, Hall-Spencer and Moore (2000) recorded profound, long-term impacts of scallop dredging on maerl habitats defined as mixed sediments built by surface layer of slow-growing, unattached coralline algae. Moran and Stephenson (2000) who measured the effects of two types of otter trawl on macrobenthos (mainly sponges, soft corals and gorgonians) found that the demersal trawl reduced the benthos density by 15.5% on each tow through the site.

LeBlanc (In press) cautioned that the results of small scale experiments, whether they measured a significant impact or not, may not reflect the impact of the commercial fishery, since the cumulative nature and spatial scale of commercial fishing disturbances are not reproduced. Nevertheless, the effect of dredging does appeared to be related to the bottom type, the benthic community and the environmental conditions of the site.

DISCUSSION

Fishing gear that touches the bottom affects the seabed habitat worldwide on the continental shelf (Kaiser *et al.* 2002) yet a measurable impact of the scallop dredge on the habitat was not detected in the sGSL (LeBlanc in press). Typically, scallop bed habitat is not structurally complex and is usually subjected to natural perturbations. The scallop fishery does have an impact on the scallop population (Arseneau et al.2007) but its impact on the species in the bycatch such as winter skate appears to be very small compared to mortality from other sources (Benoît et al. 2010; DFO 2010a). The bycatch captured by the dredge is returned to the sea and is usually in good condition. Sensitive habitats are profoundly affected by dredging (Hall-Spencer and Moore 2000) and should be protected. In the sGSL, buffer zones have been established to protect selected habitat from the effect of the dredge. But, these buffer zones are not established in all the SFAs and in some SFAs these buffer zones need to be re-evaluated.

The size range, the size frequency distribution, the growth rates, the meat weight / shell height relationships and the size at age for each scallop bed sampled in the sGSL were calculated from the data obtained during the 2001 to 2005 sea sampling program. Interestingly, these stock characteristics were very similar to those observed in the 1982 survey (Worms and Chouinard 1983). Investigations conducted in the late eighties and early nineties also provide similar values (Lanteigne and Davidson 1989, Worms and Chouinard1984, Chouinard and Mladenov 1991).

The decline of the stocks may be due to growth overfishing which occurs when too many small fish are being harvested. The scallops are not given the time to grow to the size at which the maximum sustainable yield would be obtained from the stock. The meat count measure which aims at protecting the smaller scallops from being shucked may not be accomplishing its goal. Since there is no minimum size, the blending practice allows the harvest of some scallops that have not yet reached the adult stage.

In the Québec Region, a minimum size has been added as a management measure. Presently, the scallops harvested off Magdalen Islands must have a minimum shell height of 95 mm and those fished off Gaspé must measure 100 mm or more. A minimum shell height measure would not only assure the maximum yield for each individual scallop but would also allow it to contribute to the recruitment. As reported by McGarvey el al. (1993) the older scallops are the principle contributors to recruitment. The ideal minimum size to harvest scallops in the sGSL has not been investigated. However, if a 90 mm minimum shell height would be selected for the sGSL, the meat count measures for each SFA would not have to be changed. According to the shell size and corresponding meat weight values found in Annex 2, the yield from a 90 mm scallop is often at least 50% greater than the yield of an 80mm scallop.

Looking at the data from a survey conducted in 1957, the CPUE was calculated to be as high as 8.46 kg meat/m/h on the bed west of Miscou Island. The Nepisiquit bed yields harvests up to 4.74 kg/m/h and the best yield in 1982 was 2.03 kg/m/h. Presently, in the sGSL, the CPUE calculated from the logbooks are nearly all less than 1.00 kg/m/h. In the Québec Region a CPUE classification has been developed where 1.5 kg/m/h is as a high value, between 0.85 and 1.5 kg/hm is a medium value and less than 0.85 is a low value (DFO 2010b). When the CPUE reaches 0.5 kg/hm the managers usually close the fishery (Bourdages pers. Comm.). The Gulf Region scallop logbooks may need to be slightly modified to make them easier to be properly filled-in to improve the precision of the CPUE calculation. Nonetheless, a CPUE classification for the sGSL similar to the Québec Region's classification could be developed.

In the sGSL, the scallop landings have been low since 2002. The management measures are being respected but these only seem to help to maintain a low production fishery. Since nearly 75% of the fishing licences are inactive, a strong recruitment pulse would most likely be quickly fished if management measures remain status quo. Up-to date, rotational fishing as a management measure has not been tried in the sGSL. Rotational fishing can be thought of as part of a precautionary strategy (Hart 2003). It can generate increased yield- and bio-mass-per-recruit for sea scallops compared to non-rotational fishing and rotational fishing alleviates the impact of both growth and recruitment overfishing (Hart 2003). Myers et al. (2000) showed that a rotational harvest strategy for species such as scallop would reduce the impact of indirect fish mortality on the yield per-recruit. Rotational closures have proven, in other areas, to be a very effective management strategy to increase the scallop biomass. Murawski et al. (2000) reported a 14-fold scallop biomass increase within three large areas on Georges Bank and in Southern New England, totaling 17,000 km^2, that was closed from 1994-1998. Also, the closed area contributed significantly to reduce fishing mortality of depleted groundfish stocks. According to Kaiser et al. (2002) a management regime aiming to incorporate both fisheries and habitat conservation objectives can achieve their goals through the appropriate use of a number of approaches, including 1) the total and partial exclusion of towed bottom fishing gears, 2) seasonal fishing and 3) rotational closure techniques. In the sGSL, the first two of the three approaches are already implemented; buffer zones are exclusion of towed bottom fishing gear and seasons are established. Rotational closure techniques have not been tried in the Gulf Region.

Hart (2003) calculated an optimal rotation of 6.1 years for sea scallops if the rotational fishing is true pulse fishing where all the scallops are harvested. However, for social-economical reasons, Hart (2003) suggested that a symmetric rotation which requires less concentrated effort would allow areas to be open in half the time which means a 3 year closure. The same author stressed that the only costs of rotational management are the cost of administrating and enforcing such a system and the socio-economic cost from temporary closures of the traditional fishing grounds. If scallop harvesters in the sGSL had vessel monitoring system (VMS), enforcement would be facilitated.

Smith and Rago (2004) developed a basin model to illustrate that the typical "boom and bust" effects, often attributed to environmental factors, are explained equally well by spatial variations in habitat quality, spatial concentration of fisheries, and dispersal of larvae among areas. Their results suggest that concentrating fishing effort in lower productivity areas may be an effective tool for reducing recruitment variation and improving yields. In spite of this, the economic and social consequences of such a measure would be difficult to justify. However, if the source of high productivity were emanating from a scallop farm, the scallop bed of high concentration could be fished without fear of reducing the recruitment. An example of this phenomenon has been reported by The Great Maritime Scallop Trading Co. who cultured scallop in Mahone Bay N.S. It has been observed that the adult scallop population in the bay has increased dramatically since the scallop culture activities began (Dadswell 2005). Spat emanating from a scallop farm had inadvertently seeded the over fished scallop bed in Mahone Bay, N.S. Parsons et al. (1994) have also observed this phenomenon when conducting a scallop aquaculture study in Passamaquoddy Bay, NB.

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TABLES

Table 1. Distribution of commercial scallop fishing licences and estimates of active fishing licences by SFA from 2002 to 2010.

	Status	2002	2003	2004	2005	2006	2007	2008	2009	2010
SFA 21A	Total	26	26	26	26	26	28	28	28	28
	Active	25	26	25	24	25	26	20	12	0
SFA 21B	Total	28	27	27	27	27	27	27	27	27
	Active	10	6	7	11	8	5	8	10	4
SFA21C	Total	46	48	48	48	48	48	48	48	48
	Active	24	16	13	17	8	6	4	2	1
SFA 22	Total	197	200	203	203	203	203	203	203	203
	Active	101	100	77	103	94	96	103	108	105
SFA 23	Total	75	78	78	78	78	78	78	78	78
	Active	3	0	1	2	0	1	1	2	4
SFA 24	Total	389	390	390	390	390	390	390	390	390
	Active	95	99	82	89	75	71	62	58	73
Southern Gulf	Total	761	769	772	772	772	774	774	774	774
	Active	258	247	205	246	210	205	198	192	187

Table 2. Scallop fishery seasons, open daily fishing periods, within season closed days, and regulatory meat count by SFA for 2008 to 2010.

		Scallop Fishing Area (SFA)					
		21A	21B	21C	22	23	24
Max. length of dredge (m)		6	6	6	4.88	6	5
Other gear regulation					with 50.8 mm runners		
Season open	2008	June 23 – July 25	May 19 to Aug. 9	June 23 to Aug. 30	May 1 – June 5	July 4 –Sept. 3 Nov.7 –Dec. 3	Oct. 29 – Dec. 12
	2009	June 29 – July 24	May 11 to Aug. 7	June 22 – Aug. 29	May 4 – June 6	July 2 –Sept. 1 Nov. 5 –Nov. 30	Nov 2. – Dec. 15
	2010	Closed	May 10 – Aug. 6	June 28 – July 31	May 3 to June 5	July 2 –Sept. 1 Nov. 1 –Nov. 27	Nov. 1 – Dec. 15
Time open		6:00 to 18:00	5:30 Monday to 14:00 Friday	5:30 to 20:00	6:00 to 18:00	6:00 to 18:00	6:00 to 18:00
Days closed		Saturday & Sunday	Saturday & Sunday	Sunday	Sunday	Sunday	Sunday
Meat count (number per 500g)		39	39	39	44	33	52

Table 3. Gear configuration of the scallop dredge for each SFA.

SFA	Ring size (mm)	Total length of dredge	Washers	Tow bar
21A	82.6 (3 ¼")	6 m (20')	Steel (8 max) & Chaffing gear or 2 rubbers on the vertical	----
21B		6 m (20')		----
21C		6 m (20')		----
22		4.88 m (16')		with 50.8 mm (2") runners
23		6 m (20')		----
24		5 m (16' 8")		----

Table 4. Scallop Fishing Area (SFA) and their corresponding statistical district.

Scallop Fishing Area (SFA)	Statistical districts
21A	63, 64 and 65
21B	66 and 67
21C	68, 70 71 72 and 73
22	45, 75, 76, 77, 78, 80, 82 and 83
23	92, 93, 95 and 96
24	2, 3, 10, 11, 12, 13, 46, 85, 86, 87and 88

Table 5. Scallop sea sampling dates at each site, from 2001 to 2005.

SFA	Site / Port	2001	2002	2003	2004	2005
21a	Jacquet River, NB	July 17	Aug. 1	July 8	July 21	
	Pointe-Verte, NB					July 7
	Nepisiguit Bay, NB			July 30		
21b	Miscou, NB	June 8	June 14*	June 20		
21c	Escuminac, NB	July 19	July 25*		July 28	July 21
	Val-Comeau, NB	July 10	July 4	July 11	July 8	July 13
22	Cap Pelé, NB		June 4*			
	Cap St. Louis, NB	June 5	May 20			May 31
	Cape Tormentine, NB	May 16	May 9	May 5	May 14	May 6
	Miminegash, PEI		May 22*	May 13	May 20	May 17
	West Point, PEI	May 29	May 22*	May 13*	May 6	June 2
23	Milligans Wharf, PEI	July 31	July 25*	July 30*	Aug. 4	Aug. 23
24	Fishermans Bank, PEI			Nov. 18		
	Inverness, NS			Nov. 5	Nov. 3	Oct. 31
	Margaree Hbr, NS		Nov. 6*			
	Murray Hbr, PEI	Dec. 3*	Nov. 22*			
	Beach Point, PEI				Nov. 19	Nov. 16
	Skinners Cove, NS	Nov. 14	Nov. 30*	Nov. 12*	Nov. 30*	Dec. 13*

* lab sample only.

Table 6. Summary of at-sea sampling data and the calculated catch rates, CPUE, catch density, percentage of clappers and the number of lobsters during the fishing day for 2001 to 2005.

2001								
SFA	Site	No. of tows	Total no. of scallops measured	Catch rate kg/hr	CPUE kg/hr* m	Catch Density scallops/m^2	% clappers	No. of lobsters
21a	Jacquet River	9	2497	5.8	1.11	0.010	0.8	0
21b	Miscou	7	1138	7.6	1.24	0.009	1.5	0
21c	Val-Comeau	5	371	2.7	0.74	0.014	1.1	0
	Escuminac	15	1494	5.9	1.00	0.009	2.3	1
22	Cape Tormentine	20	1879	5.8	1.26	0.012	0.6	0
	West Point	7	1135	6.8	1.40	0.011	1.6	0
	Cap St. Louis	6	453	2.4	0.52	0.012	2.6	0
23	Milligans Wharf	10	704	2.2	0.43	0.010	15.6	0
24	Skinners Cove	9	544	5.7	1.21	0.011	0.4	0
2002								
SFA	Site	No. of tows	Total no. of scallops measured	Catch rate kg/hr	CPUE kg/hr* m	Catch Density scallops/m^2	% clappers	No. of lobsters
21a	Jacquet River	7	584	3.0	0.70	0.012	9.7	0
21c	Val-Comeau	9	280	1.3	0.25	0.003	5.4	0
22	Cape Tormentine	10	1338	6.2	1.38	0.035	11.3	0
	Cap St. Louis	2	199	4.3	0.89	0.009	0	0
2003								
SFA	Site	No. of tows	Total no. of scallops measured	Catch rate kg/hr	CPUE kg/hr* m	Catch Density scallops/m^2	% clappers	No. of lobsters
21a	Jacquet River	10	1157	4.8	1.10	0.016	15.2	0
21b	Miscou	1	200	6.5	1.08	0.011	9.0	0
21c	Val-Comeau	14	1515	3.5	0.93	0.018	3.4	0
22	Cape Tormentine	16	1928	4.4	1.02	0.052	16.1	3
	Miminegash	8	672	3.4	0.71	0.013	2.1	1
24	FishermansBank	21	1862	6.6	1.22	0.031	19.8	7
	Inverness	6	2040	3.4	0.71	0.054	14.9	0
2004								
SFA	Site	No. of tows	Total no. of scallops measured	Catch rate kg/hr	CPUE kg/hr* m	Catch Density scallops/m^2	% clappers	No. of lobsters
21a	Jacquet River	9	1106	4.2	0.97	0.017	13.7	0
21c	Val-Comeau	5	414	3.0	0.81	0.015	2.9	0
	Escuminac	10	723	4.8	0.79	0.012	1.2	1
22	Cape Tormentine	9	1312	4.7	1.27	0.036	20.7	0
	West Point	8	1648	7.4	1.51	0.042	14.7	1
	Miminegash	15	1669	6.0	1.26	0.041	3.8	1
23	Milligans Wharf	13	862	3.1	0.63	0.008	0.7	0
24	Beach Point	14	1233	5.3	0.98	0.019	7.7	6
	Inverness	9	1923	6.8	1.57	0.039	8.9	0

Table 6 (continued).

2005								
SFA	Site	No. of tows	Total no. of scallops measured	Catch rate kg/hr	CPUE kg/hr* m	Catch Density scallops/m^2	% clappers	No. of lobsters
21a	Pointe Verte	10	1458	6.2	1.44	0.017	6.0	2
21c	Val-Comeau	6	393	3.1	0.83	0.007	1.0	0
	Escuminac	14	223	0.7	1.5	0.002	1.4	0
22	Cape Tormentine	14	1181	4.2	0.99	0.020	7.1	1
	Miminegash	12	1050	5.7	1.15	0.013	0.4	1
	Cap St. Louis	7	909	4.6	0.93	0.024	0.3	0
23	Milligans Wharf	7	558	4.4	0.91	0.012		0
24	Beach Point	4	218	3.5	0.60	0.011	4.6	0
	Inverness	7	922	6.4	1.48	0.011	3.0	0

Table 7. The average meat weight and age of 90 mm and 100 mm scallop from each SFA.

	Shell height			
	90 mm		100 mm	
SFA	Avg meat weight	Avg age	Avg meat weight	Avg Age
21	13.4 ± 2.5	5.3 ± 0.5	17.9 ± 3.4	7.1 ± 1.0
22	13.3 ± 2.2	5.7 ± 0.8	16.3 ± 3.5	6.6 ± 0.9
23	14.3 ± 1.6	5.7 ± 1.2	16.9 ± 1.9	7.1 ± 0.9
24	12.3 ± 2.4	7.2 ± 1.6	14.6 ± 2.7	9.7 ± 2.9

Table 8. Yearly average meat weight for a 90 mm scallop and average meat weight corresponding to meat count regulation.

SFA	Wharf – nearest to bed	Average Meat Weight (g) for a 90 mm scallop 2001	2002	2003	2004	2005	Average Meat Weight (g) corresponding to meat count
21A	Jacquet River	11.4	9.5	10.6	11.6	12.1	12.8
21B	Miscou	14.9	14.4	13.6			12.8
21C	Val-Comeau	13.9	12.3	13.8	15.3	13.9	12.8
21C	Escuminac	11.5	11.2		13.4	10.8	12.8
22	Cape Tormentine	12.8	10.6	11.06	14.2	10.8	11.4
22	Cap Pelé		8.7				11.4
22	West Point	14.6	11.7	13.91	13.6	12.1	11.4
22	Cap St. Louis	14.7	13.5			13.0	11.4
22	Miminegash		12.9	12.99	14.3	12.3	11.4
23	Milligans Wharf	12.0	13.7	13.4	13.5	11.8	15.2
24	Skinners Co.	12.4	11.9	12.64	13.6	12.8	9.6
24	Fishermans Bank			11.22			9.6
24	Murray Hbr	12.8	12.8		13.7	11.1	9.6
24	Inverness			9.74	9.4	9.1	9.6
24	Margaree Hbr		10.7				9.6

Table 9. Detailed description of the lobster habitat classification (from Comeau 2007).

Lobster Habitat	Description
Type I.	Prime lobster ground: complex habitat composed of numerous small to middle size boulders (diameter >25 cm) on a gravel or small cobble substrate, or a mixture of gravel-mud-sand.
Type II	Good lobster ground: small to middle size boulders on a softer substrate, but the complex assemblage of small to middle size boulders formed reefs that are separated, but are located at very close proximity
Type III	Marginal lobster ground: similar to type II but the reef type formations are far apart. Between these reef formations a simple habitat composed of gravel, mud and/or sand or hard sandstone bottom (poor lobster habitat) is observed.
Type IV	Poor lobster habitat: simple habitat composed of soft material (such as gravel, sand and mud) or hard bottom (sandstone or granite bottom) with no boulder size rocks.

FIGURES

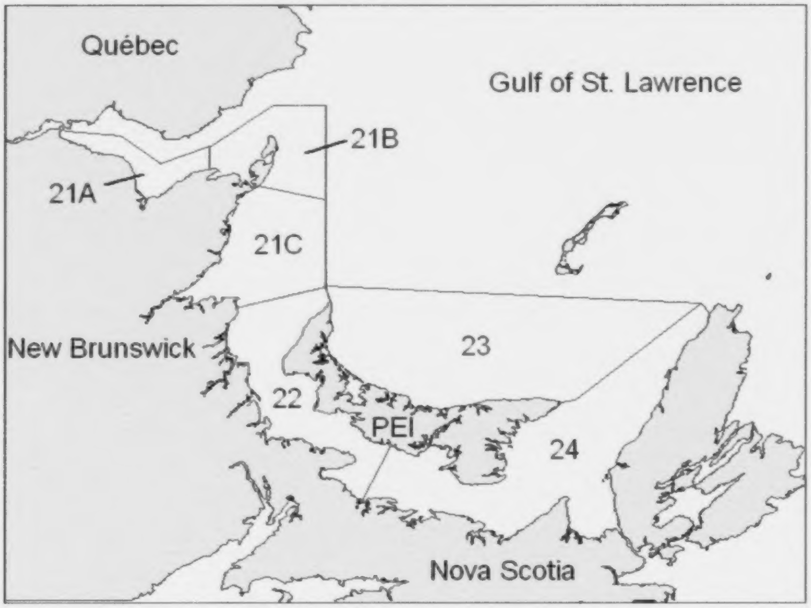


Figure 1. The Scallop Fishing Areas (SFA) in the Gulf Region.

Figure 2. Digby-type dredge commonly used in the Gulf Region.

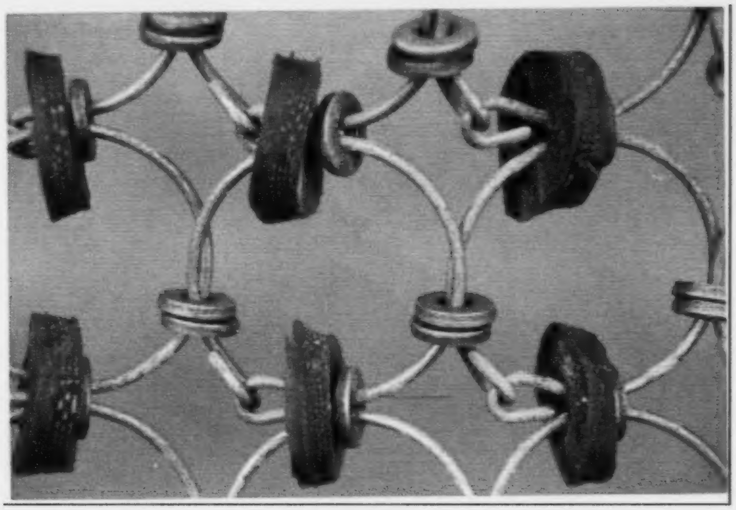
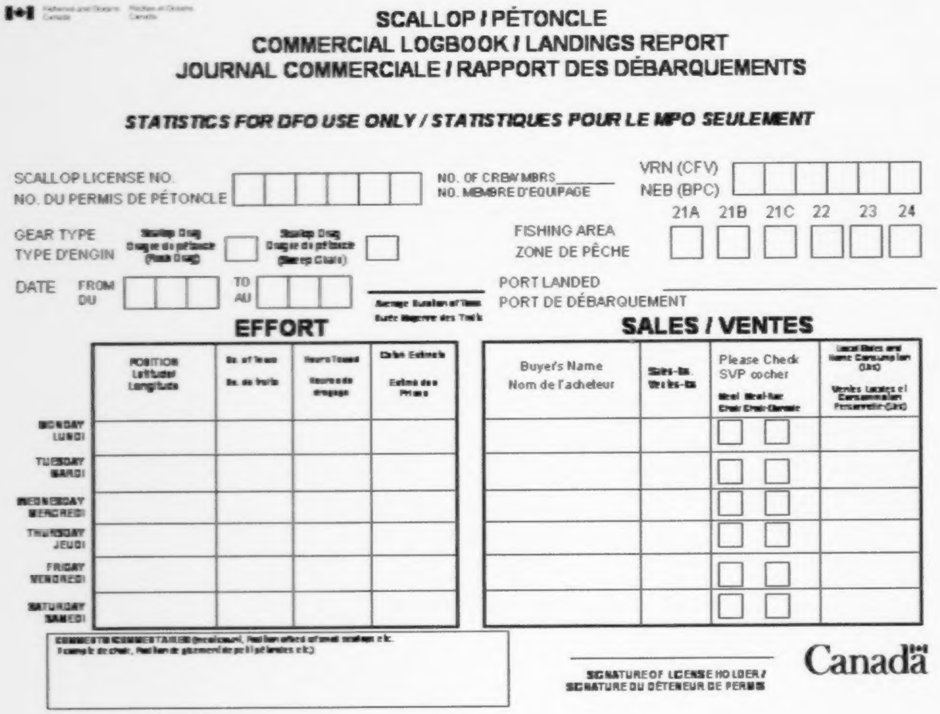


Figure 3. Rings with steel washers and vertically placed rubber washers.



SCALLOP / PÉTONCLE
COMMERCIAL LOGBOOK / LANDINGS REPORT
JOURNAL COMMERCIALE / RAPPORT DES DÉBARQUEMENTS

STATISTICS FOR DFO USE ONLY / STATISTIQUES POUR LE MPO SEULEMENT

SCALLOP LICENSE NO.
NO. DU PERMIS DE PÉTONCLE

NO. OF CREW MBRS
NO. MEMBRE D'EQUIPAGE

VRN (CFV)
NEB (BPC)

GEAR TYPE
TYPE D'ENGIN

FISHING AREA
ZONE DE PÊCHE
21A 21B 21C 22 23 24

DATE FROM / DU TO / AU

PORT LANDED
PORT DE DÉBARQUEMENT

EFFORT

	POSITION Latitude/ Longitude			
MONDAY LUNDI				
TUESDAY MARDI				
WEDNESDAY MERCREDI				
THURSDAY JEUDI				
FRIDAY VENDREDI				
SATURDAY SAMEDI				

SALES / VENTES

Buyer's Name Nom de l'acheteur		Please Check SVP cocher	

SIGNATURE OF LICENSE HOLDER / SIGNATURE DU DÉTENEUR DE PERMIS

Canada

Figure 4. Scallop logbook for the commercial fishery.

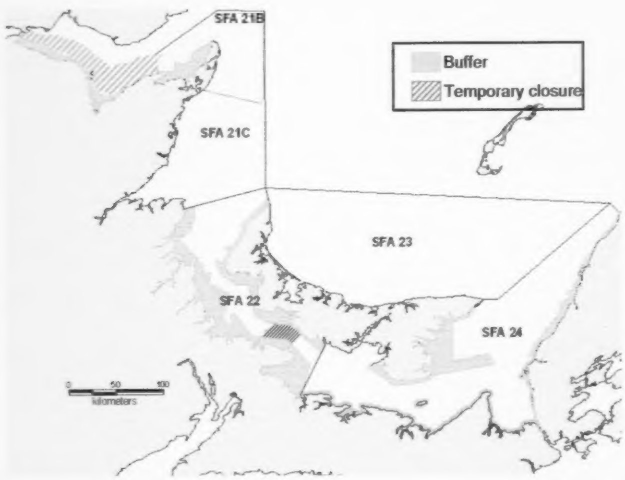


Figure 5. Buffer zones and temporary closure areas in the Gulf Region in 2010.

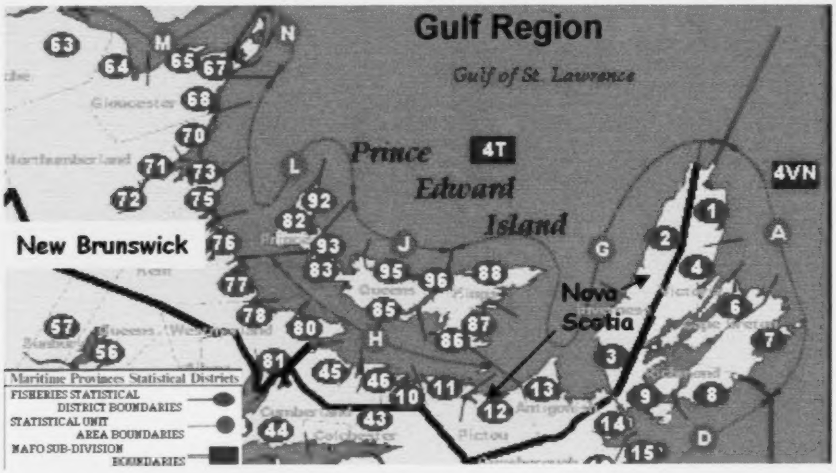


Figure 6. Map of statistical district for the Gulf Region.

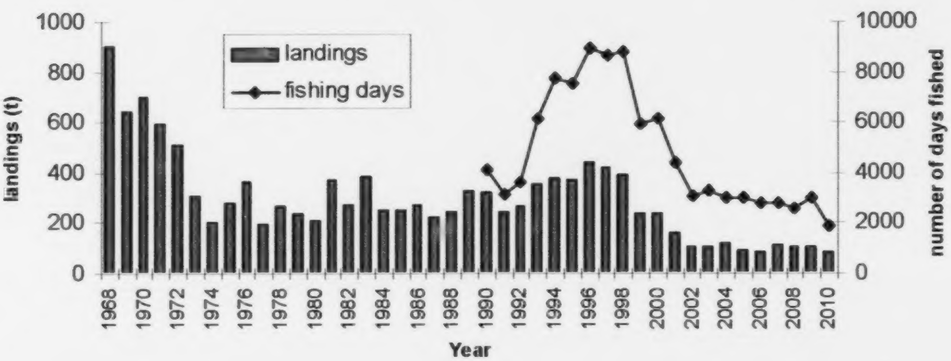


Figure 7. Recorded sea scallop landings (t of meat weight) and the number of days fished in the southern Gulf of St. Lawrence, 1968 to 2010.

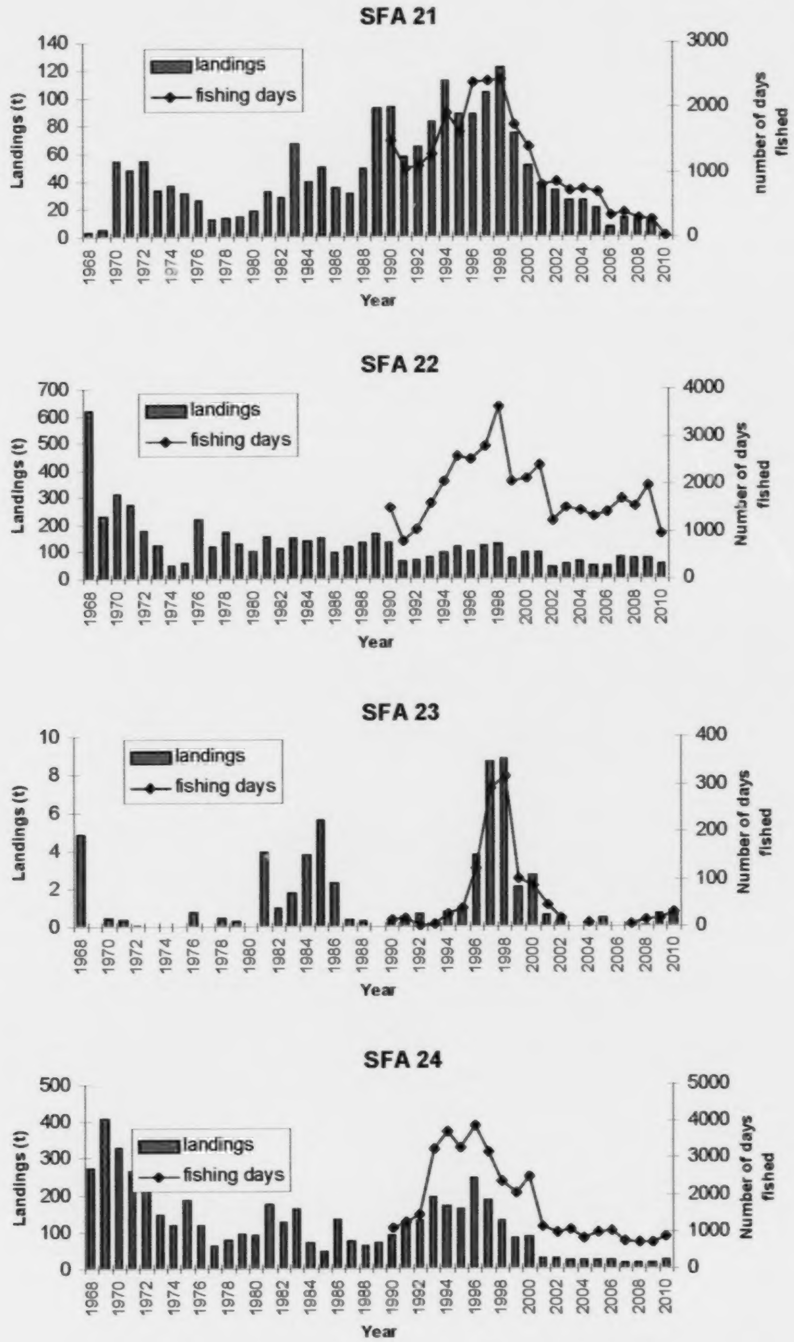


Figure 8. Recorded sea scallop landings (t of meat weight) and the number of days fished by SFA, 1968 to 2010.

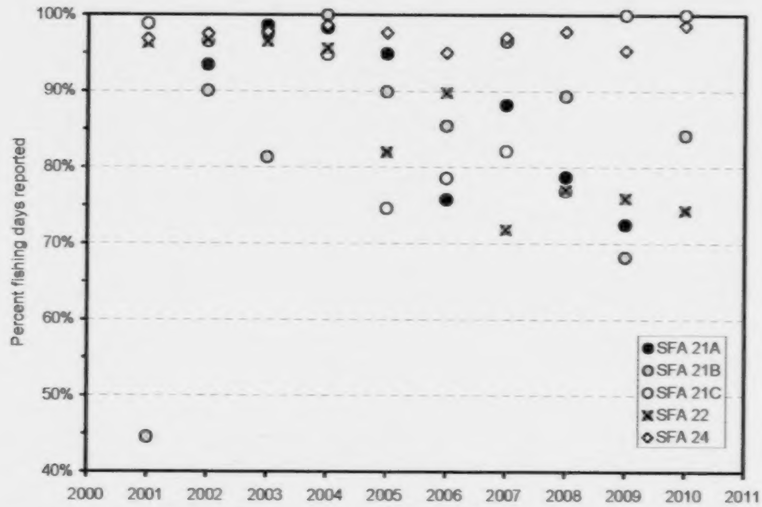


Figure 9. The percentage of the fishing days recorded in logbooks versus the fishing days estimated from purchase slips by SFA for 2001 to 2010.

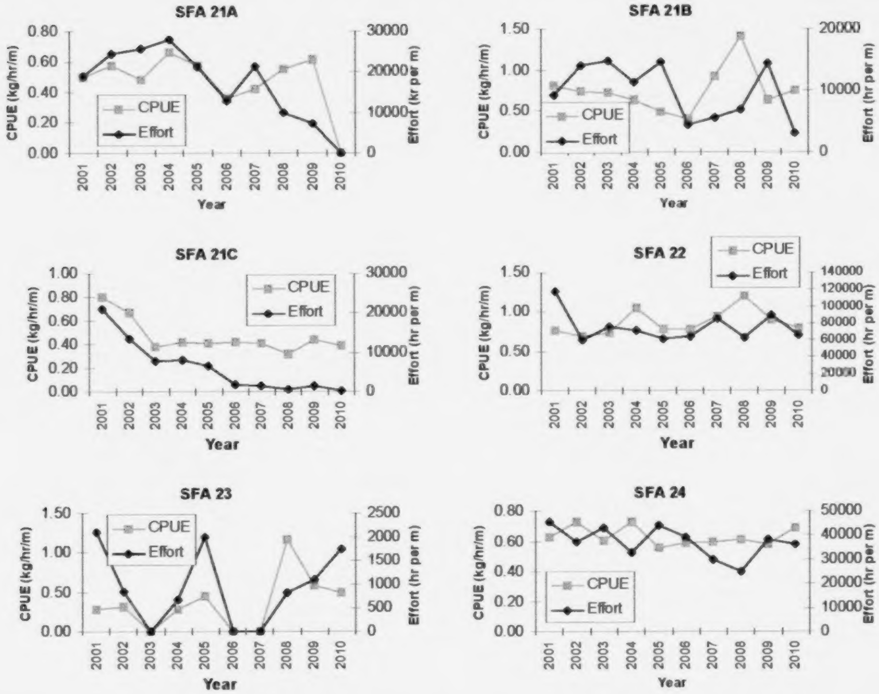


Figure 10. CPUE (kg per hr per m of dredge) and estimated effort (hr per m of dredge) for the six SFAs in the southern Gulf of St. Lawrence based on logbook data. Effort not recorded in logbooks is estimated from the CPUE values corrected for the total landings.

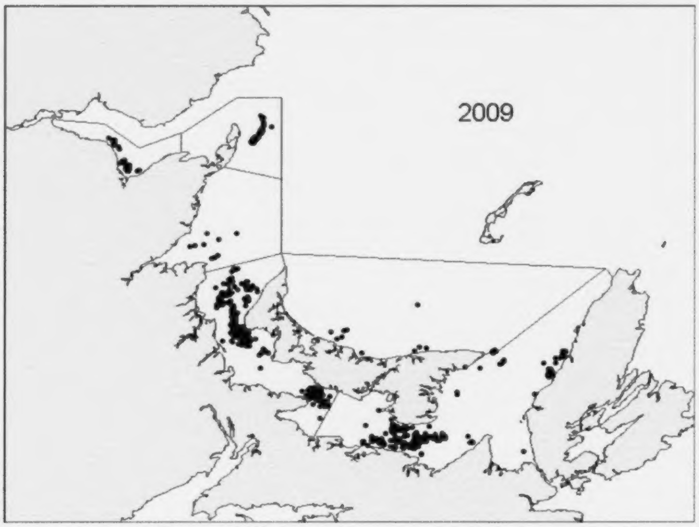


Figure 11. Map of fishing effort positions reported in the 2009 scallop harvesters' logbook.

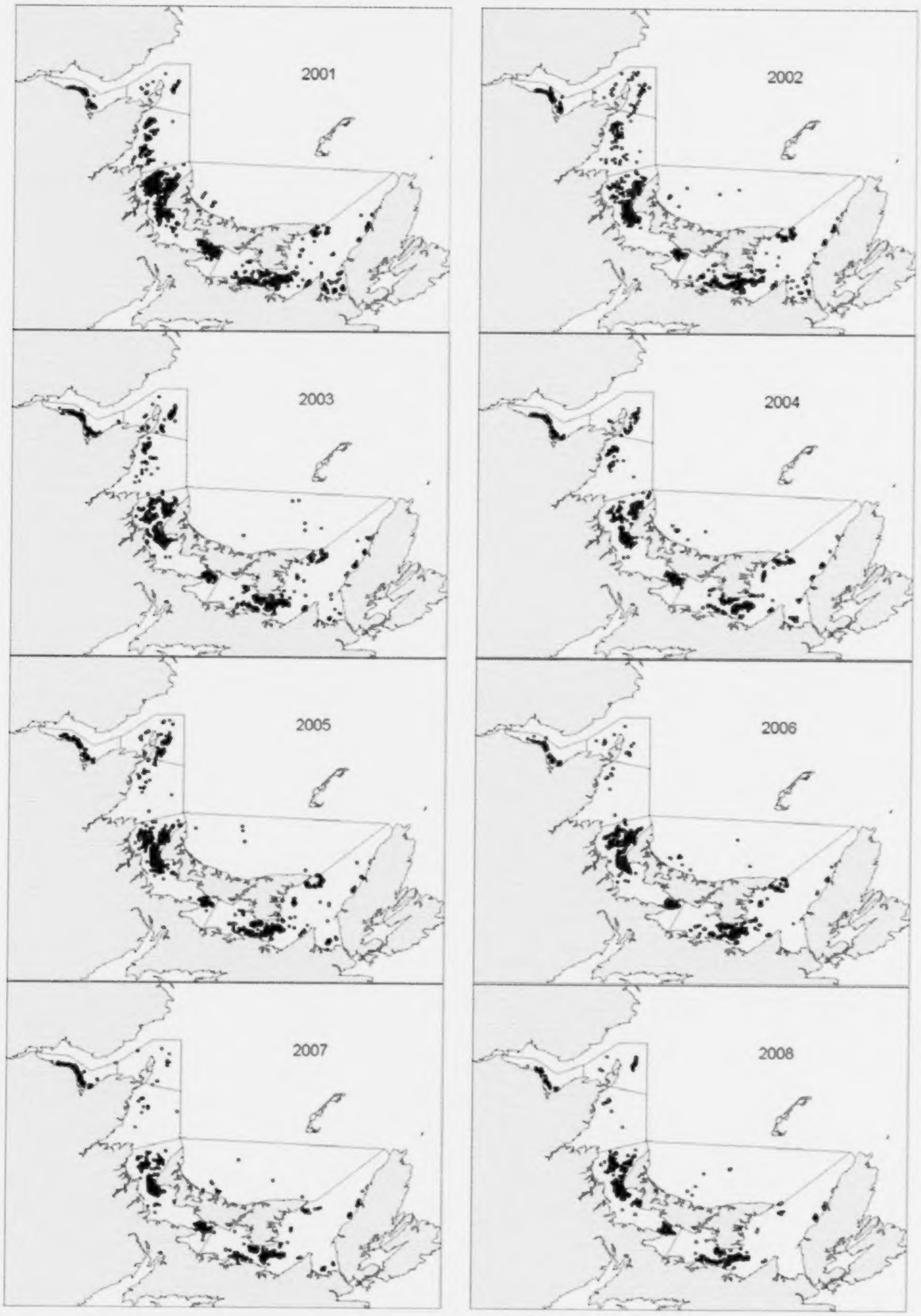


Figure 12. Map of fishing effort positions reported in the 2001 to 2008 from scallop harvesters' logbook.

Figure 13. Sea sampling sites in the southern Gulf of St. Lawrence in 2001, 2002, 2003. 2004 and 2005 in each Scallop Fishing Area (SFA) 21A, B and C, 22, 23 and 24.

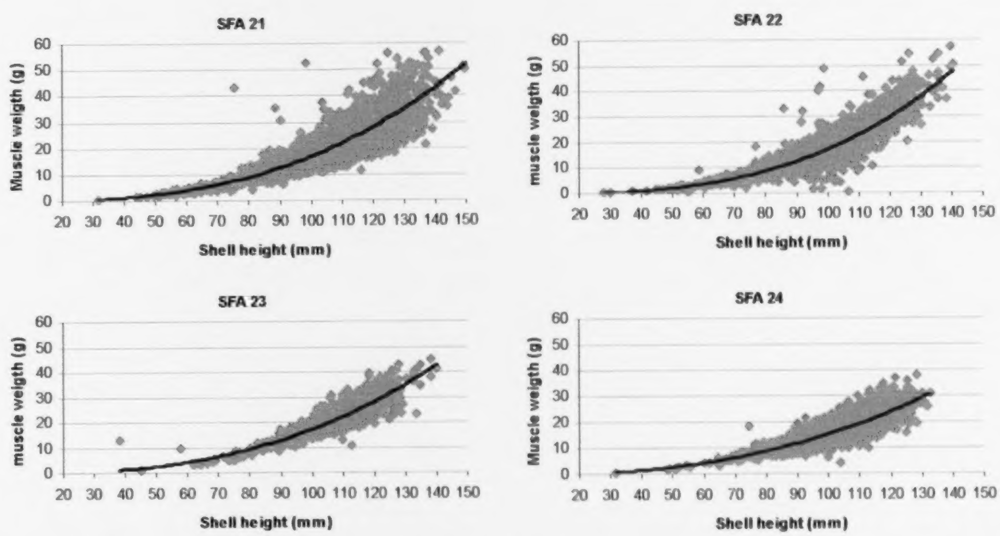


Figure 14. Meat weight to shell height relationships of scallops by SFA based on at-sea samples during 2001 to 2005.

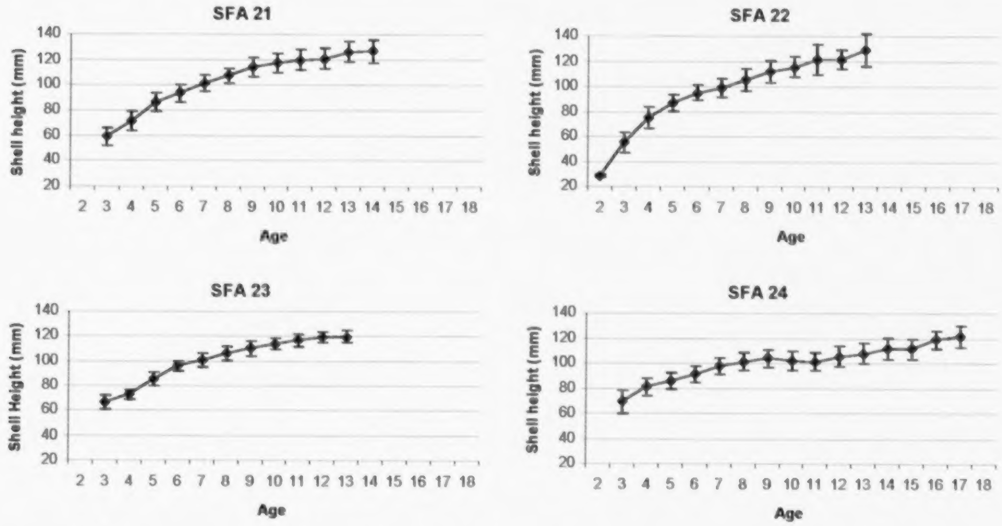


Figure 15. Estimated shell height at age of sea scallop by SFA based on at sea sampling, 2001 to 2005.

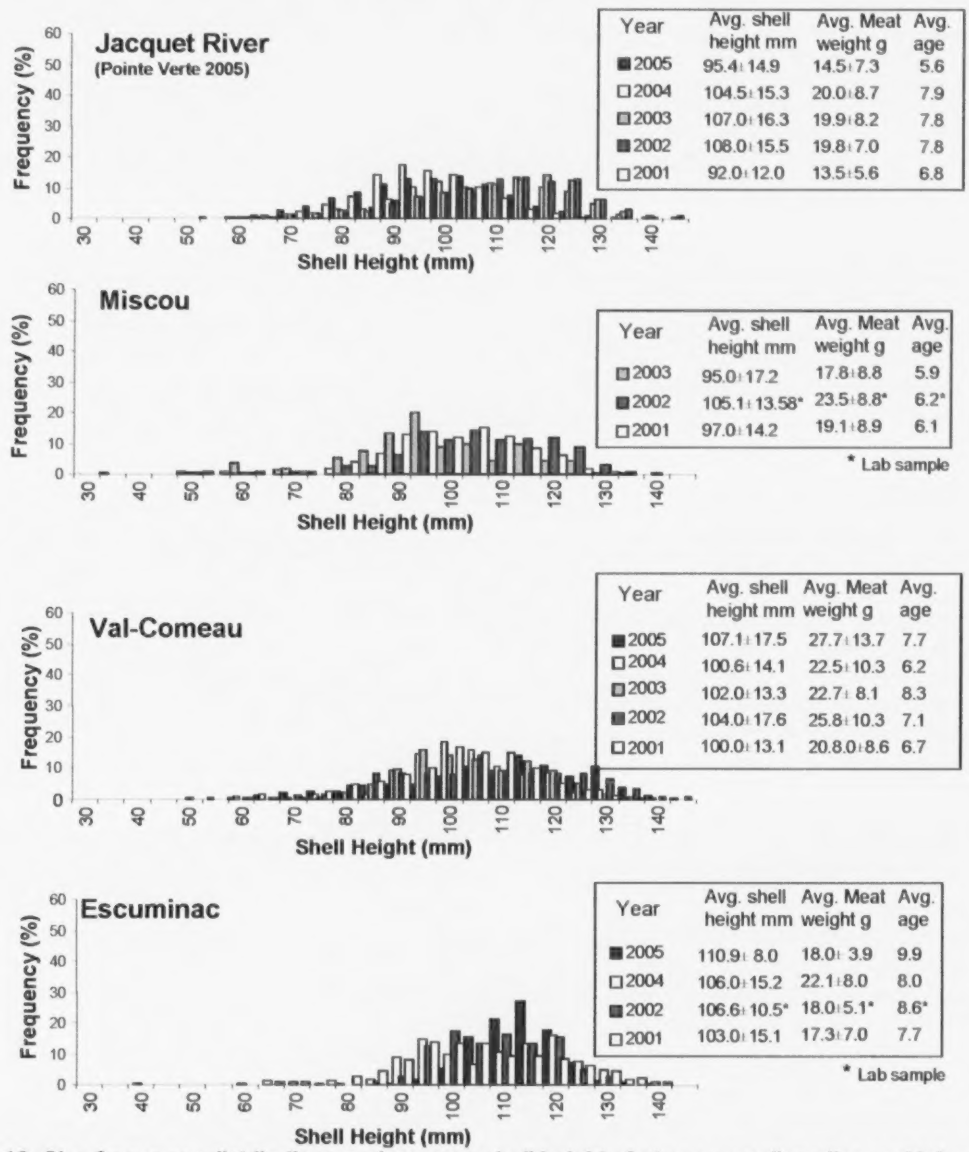


Figure 16. Size frequency distributions and average shell height of at-sea sampling sites and lab samples in SFA 21.

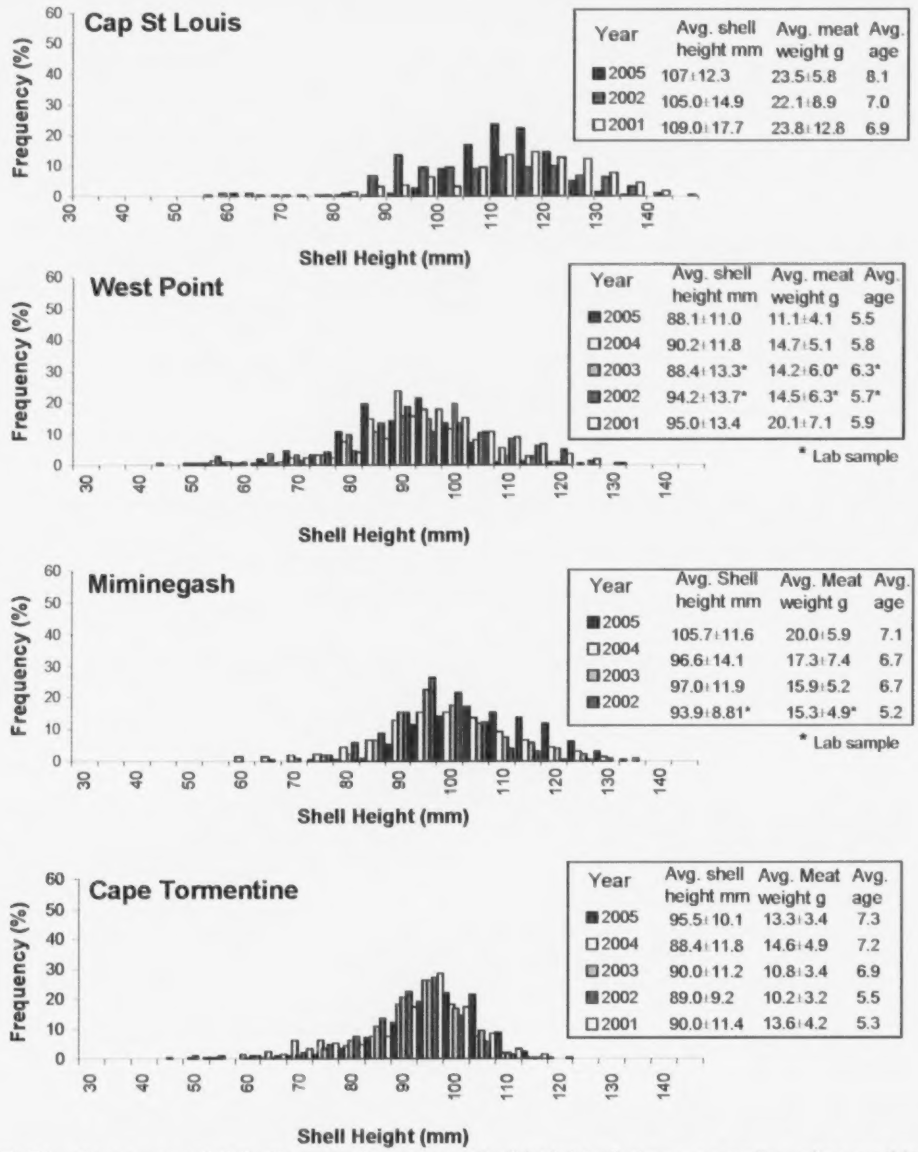


Figure 17. Size frequency distributions and average shell height of at-sea sampling sites and lab samples in SFA 22.

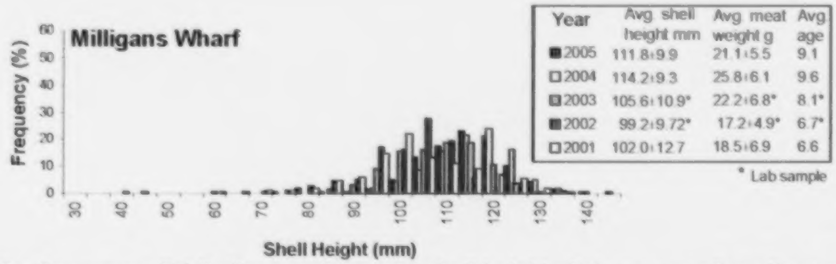


Figure 18. Size frequency distributions and average shell height of at-sea sampling sites and lab samples in SFA 23.

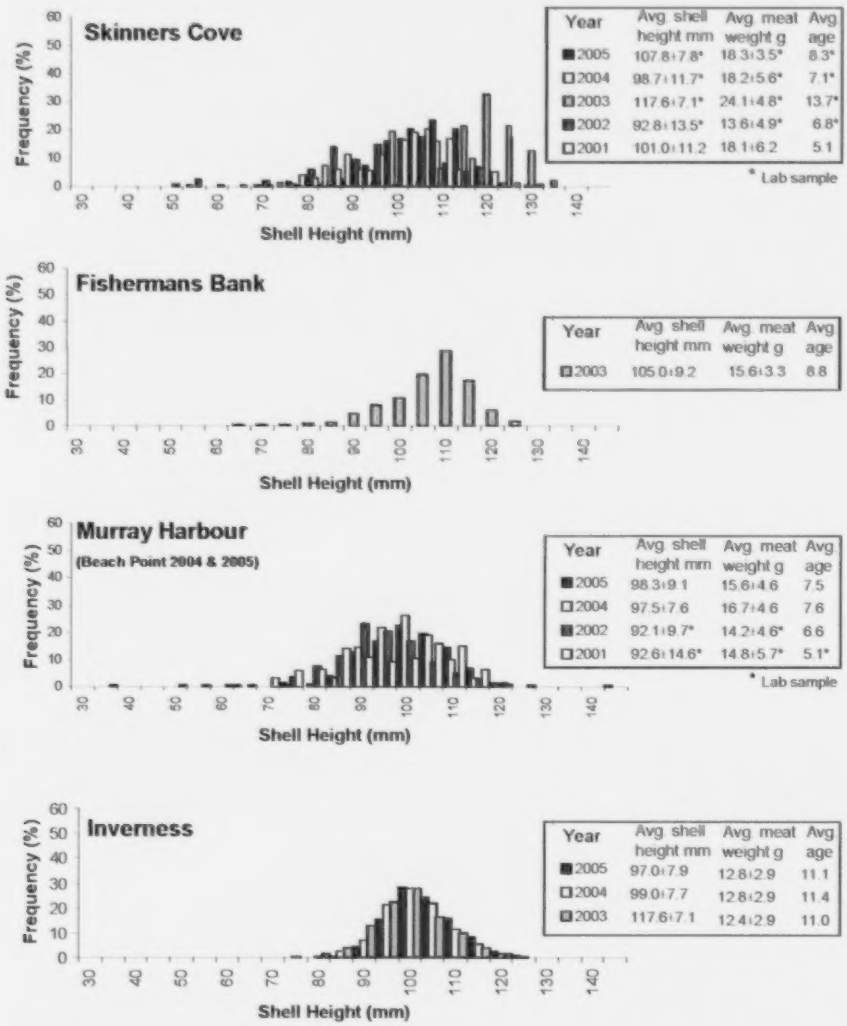


Figure 19. Size frequency distributions and average shell height of at-sea sampling sites and lab samples in SFA 24.

ANNEXES

Annex 1. Gear configuration of commercial fishing vessels that participated in the at-sea sampling in each SFA.

Drag type	Digby drag with teethed buckets	Digby side drag with teethed buckets	Digby drag with teethed buckets	Digby drag with teethed buckets
Site	**Jacquet River**	**Miscou**	**Val-Comeau**	**Escuminac**
Drag width (m)	4.3	6.1	3.7	6.1
Number of buckets	7	10	6	13
Ring size (mm)	82.6	82.6	82.6	82.6
Washer type	Steel	Steel	Steel	Steel
Tow bar runners	none	none	None	None
Average tows per day	16	25	20	35
Average duration of tows (min.)	30	30	30	12
Average dumping time (min.)	5	5	4	3
Speed of tow (kt)	2	2	2.2	2.6
Number of crew	3	3	3	3
Years of experience of Captain	31	42	30	5

Site	**Cape Tormentine**	**West Point**	**Cap St Louis**	**Miminegash**
Drag width (m)	4.3	4.88	4.6	4.8
Number of buckets	8	12	10	12
Ring size (mm)	82.6	82.6	82.6	82.6
Washer type	Steel with rubber on vertical	Steel with rubber on vertical	Steel with rubber on vertical	Steel with rubber on vertical
Tow bar runners	wheel	ski	round	wheel
Average tows per day	36	24	15	22
Average duration of tows (min.)	12	20	30	20
Average dumping time (min.)	10	10	5	5
Speed of tow (kt)	2	2	2.5	2.5
Number of crew	2	2	2	2
Years of experience of Captain	10	32	38	32

Site	**Milligans Wharf**	**Skinners Cove**	**Fishermans Bank, PEI**	**Inverness, NS**
Drag width (m)	5.1	4.7	5.4	4.3
Number of buckets	12	6	7	7
Ring size (mm)	82.6	82.6	82.6	82.6
Washer type	Steel with rubber on vertical	Steel with rubber on vertical	Steel with rubber on vertical	Steel with rubber on vertical
Tow bar runners	ski	None	none	none
Average tows per day	20	70	48	30
Average duration of tows (min.)	25	10	15	15
Average dumping time (min.)	5	3	5	5
Speed of tow (kt)	2	2	2.5	2.7
Number of crew	1	3	2	3
Years of experience of Captain	8	36	21	15

Annex 2. The age, shell height and related meat weight and meat count/ 500g of scallops obtained from various beds in 2003.

SFA	Site	Age	Shell Height (mm)	SD	Meat Weight (g)	Meat Count /500g
21A	**Jacquet River**	4	56.6	-	2.3	217
		5	73.6	3.8	6.2	80
		6	89.6	5.7	10.0	50
		7	100.4	3.8	14.6	34
		8	108.2	4.5	19.8	25
		9	112.8	5.6	22.8	22
		10	117.7	3.3	24.8	20
		11	120.7	3.1	26.4	19
21B	**Nepisiguit**	4	63.7	4.9	4.3	116
		5	-	-	-	-
		6	84.4	0.7	8.5	59
		7	105.1	2.9	16.3	31
		8	108.9	4.0	18.7	27
		9	113.5	3.7	20.6	24
		10	115.7	2.8	23.7	21
		11	124.4	5.1	24.5	20
		12	124.3	6.7	20.1	25
21B	**Miscou**	2	31.7	-	0.4	1250
		3	50.2	3.9	2.2	233
		4	61.2	5.9	4.5	111
		5	84.1	3.0	11.4	44
		6	90.8	3.3	14.6	34
		7	96.9	3.4	17.4	29
		8	105.4	6.2	22.4	22
		9	115.7	-	32.2	16
		10	117.3	1.4	31.5	16
21C	**Val-Comeau**	6	83.1	3.9	11.5	43
		7	92.3	3.6	15.2	33
		8	99.4	4.3	18.8	27
		9	102.8	1.3	18.5	27
		10	112.7	4.4	27.4	18
		11	115.3	2.1	28.7	17
		12	120.5	0.7	41.3	12
		13	125.3	-	39.3	13

Annex 2 (continued).

SFA	Site	Age	Shell Height (mm)	SD	Meat Weight (g)	Meat Count /500g
22	Miminegash	4	71.5	6.6	7.8	64
		5	82.7	4.0	10.0	50
		6	92.2	3.5	14.1	35
		7	94.2	5.7	15.2	33
		8	103.0	7.9	18.6	27
		9	105.1	2.5	21.5	23
		10	111.6	5.0	25.5	20
22	West Point	3	50.6	-	2.3	217
		4	62.8	5.5	4.6	108
		5	79.9	4.6	10.6	47
		6	91.4	4.0	15.1	33
		7	96.7	4.9	16.9	30
		8	103.0	1.7	22.2	22
		9	105.4	2.1	25.2	20
		10	112.1	2.6	26.6	19
22	Cape Tormentine	3	49.9	-	2.0	250
		4	69.4	6.7	5.1	98
		5	76.3	5.8	7.1	70
		6	83.5	3.7	8.9	56
		7	87.5	3.9	10.9	46
		8	92.2	2.9	11.7	43
		9	94.2	2.3	14.4	35
		10	103.2	-	17.1	29

SFA	Site	Age	Shell Height (mm)	SD	Meat Weight (g)	Meat Count /500g
23	Milligans Shore	3	45.0	-	1.3	385
		4	-	-	-	-
		5	-	-	-	-
		6	90.4	5.8	14.0	36
		7	94.3	4.5	15.6	32
		8	103.1	4.1	20.0	25
		9	104.5	5.0	20.0	25
		10	114.9		25.3	20
		11	113.3	4.3	25.0	20
		12	118.6	0.0	32.4	15

Annex 2 (continued).

SFA	Site	Age	Shell Height (mm)	SD	Meat Weight (g)	Meat Count /500g
24	**Skinner's Cove**	7	95.7	4.4	14.4	35
		8	105.6	-	21.0	24
		9	107.9	-	18.7	27
		10	-	-	-	-
		11	111.0	-	22.4	22
		12	113.0	5.9	22.9	22
		13	115.4	7.6	25.1	20
		14	118.7	4.4	25.5	20
		15	120.7	5.3	24.8	20
		16	122.6	6.9	26.8	19
		17	128.0	4.7	31.9	16
		18	-	-	-	-
		19	123.6	-	25.0	20
24	**Fishermans Bank**	6	88.6	4.1	11.2	45
		7	92.5	1.8	13.0	39
		8	96.1	4.8	12.4	40
		9	104.2	4.3	15.9	31
		10	105.7	4.1	17.0	29
		11	107.9	4.4	18.1	28
		12	113.7	1.7	19.8	25
		13	108.2	-	16.5	30
24	**Inverness**	7	81.2	4.8	6.6	76
		8	86.4	5.8	9.0	55
		9	90.7	-	9.3	54
		10	93.6	3.8	11.1	45
		11	95.2	3.4	11.1	45
		12	99.5	3.0	12.6	40
		13	101.3	5.6	14.8	34
		14	100.4	5.7	13.9	36
		15	99.8	-	11.4	44
		16	107.6	-	18.7	27